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How do individuals and groups perceive wetland functioning? Fuzzy cognitive mapping of wetland perceptions in Uganda

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Highlights

- Fuzzy cognitive mapping (FCM) is used to analyse perceptions of a wetland system.
- Stakeholders perceive wetland conservation and livelihoods as convergent goals.
- Farmers' and government officials' views on wetland differ most from other groups.
- Individual maps better fitted to find divergent perceptions than group maps.
- Nested approach of bottom-up and top-down wetland management should be considered.

Abstract

Wetlands are critical natural resources around the globe, providing many direct and indirect benefits to local communities. However, wetland degradation and conversion to other land uses are widespread. Sustainable wetland management requires an understanding of stakeholders' perceptions of the ecosystem and its management. This paper uses fuzzy cognitive mapping to capture individual stakeholder perceptions and group knowledge of wetland ecosystems in order to assess areas of consensus and opposing interests between different stakeholders and to develop future management scenarios. For this purpose, the Rushebeya-Kanyabaha wetland, which is one of the few wetlands in southwest Uganda that is still largely intact, is used as a case study. Our findings reveal differences in perceptions between different resource users. Papyrus harvesters, beekeepers, fishermen, wetland non-users, and hunters associate the largest livelihood benefits with a wetland conservation scenario, while farmers and government officials perceive increased agricultural production in the wetland area to be more livelihood enhancing. This poses a challenge to sustainable wetland management. The scenario results also suggest that centralized top-down laws and rules on wetland use are not sufficient for maintaining the wetland ecosystem. Therefore, there is a need to develop shared understanding through bottom-up approaches to wetland management that are nested within national regulatory frameworks, ideally combined with awareness building and knowledge sharing on the ecological benefits of the wetland.

Keywords: wetlands; fuzzy cognitive mapping; stakeholder perceptions; conservation; natural resource management; Uganda

1. Introduction

Wetlands are one of the most valuable and productive ecosystems on this planet (Moreno-Mateos et al., 2012; Nabahungu and Visser, 2011), providing up to 40 per cent of the world's renewable ecosystem services (Zedler and Kercher, 2005); yet, they are among the most threatened (Rebelo et al., 2010). Human activity has significantly altered the dynamics of wetlands (Barbier et al., 1997) and the rate at which these ecosystems degrade and convert to other land uses is higher than any other ecosystem (Millennium Ecosystem Assessment, 2005). Population growth, agricultural expansion, increasing access to markets, upland soil degradation, and weak regulation are just a few of the common pressures driving wetland degradation and land use change (Chapman et al., 2001; Hartter and Southworth, 2009; Langan and Farmer, 2014). Wetland degradation reduces the ecosystem's productivity, which results in reduced water supply and causes a sudden release of CO_2 (Joosten, 2009; Saunders et al., 2012). In addition, soil nutrient levels, biodiversity and wildlife rapidly decrease, water pollution increases, and wetland vegetation and provision of associated products, including medicinal plants, are lost (Dugan, 1993; Schuyt, 2005). Ultimately, wetland degradation affects peoples' livelihoods and their well-being (Morrison et al, 2013; van Dam et al., 2011; Schuyt, 2005).

Explaining the drivers of wetland degradation and loss requires a better understanding of the complex human-nature interactions within these socio-ecological systems. Resource decision-making contexts are often characterized by high social, economic and ecological stakes, low levels of control, heterogeneity of stakeholders, and a lack of data (Gray et al., 2015). To capture the complexity of these socio-ecological systems and their dynamics, there is a need for more inclusive participatory approaches. These approaches can also help to identify potential management solutions in a studied (Gray et al., 2015; Hartter and Ryan, 2010; Özesmi and Özesmi, 2004). In addition, participatory approaches can provide important insights into the functioning of the system and highlight areas of consensus and diverging views between different types of users and uses. In this study, we use fuzzy cognitive mapping (FCM) as a bottom-up and systems approach to elicit stakeholder's internal constructs of their environment.

FCM is a semi-quantitative dynamic modelling approach to structure knowledge and perceptions (Gray et al., 2015; Kok, 2009). FCM was developed by Kosko (1986) and has its roots in graph theory (Biggs et al., 1976) and cognitive mapping theory

(Axelrod, 1976). Fuzzy cognitive maps are directed graphs that exist of concepts – also named variables – which are represented as points or nodes in the system, and links between those variables (Axelrod, 1976; Harary et al., 1965; Kosko, 1986). The variables can be anything from a quantitative measure of a natural ecosystem aspect, such as pH levels in a water body, to abstract ideas like political or cultural forces (Mouratiadou and Moran, 2007). Each link is described by the direction (positive or negative) of the relationship and its strength, measured in a weight in the interval of [-1, 1] (Kosko, 1986; Novak and Cañas, 2008). Cognitive mapping aims to reveal people's cognitive models of a studied system. FCM is built on the foundations of constructivist psychology (Gray et al., 2014) and assumes that individuals have mental models, which internally and interactively construct knowledge by creating associative representations that help structure and interpret the external environment (Gray et al., 2015; Halbrendt et al., 2014). Fuzzy cognitive maps can thus be considered organized internal representations (structured understanding and knowledge of workings) of an external reality (a general or specific context or system). Consequently, they can be used analyse the perceived structure of a system, and also to analyse its perceived functioning through the development of semi-quantitative scenarios (Henly-Shepard et al., 2015) that enable comparison between current and projected states in the case of a change or intervention in the system. Whereas FCM research has traditionally made predominant use of expert respondents (e.g. Amer et al., 2011; Hobbs et al., 2002; Radomski and Goeman, 1996), an increasing number of FCM applications include non-expert and local stakeholders to inform the development of management strategies and policies (e.g. Gray et al., 2012a; Meliadou et al., 2012; Mouratiadou and Moran, 2007; Özesmi and Özesmi, 2004; Papageorgiou and Kontogianni, 2012).

This paper presents an application of FCM to elicit stakeholder's perceptions in the Rushebeya-Kanyabaha wetland in southwest Uganda, which is one of the few relatively intact wetlands in the area. The study includes local stakeholders, such as direct wetland users (e.g. farmers and fishermen) and government officials. The aim of this paper is twofold. First, the study elicits local stakeholders' perceptions on wetland functioning. In order to do this, both individually and collectively constructed fuzzy cognitive maps are used to understand perceptions, attitudes and beliefs between different wetland stakeholder groups. To do this, individually elicited maps are aggregated by stakeholder category. This analysis is complemented by a map constructed jointly by different stakeholders. The outcome of this map is thus based on negotiated group knowledge and therefore might capture some stakeholder dynamics not reflected on individual maps (Özesmi and Özesmi, 2004). Individually constructed maps are not subjected to group dynamics and may therefore represent group knowledge in a more equitable way (Gray et al., 2014). Our study aims to point out whether interesting differences between both approaches emerge, as most studies have used group-developed maps to understand a social-ecological system. Second, aggregated stakeholder's fuzzy cognitive maps are used to run the following three management scenarios: i) wetland conservation; ii) wetland cultivation and iii) enforcement of laws and rules. Based on stakeholder's perceptions, these scenarios explore development of the studied system under different regimes, which in turn can inform ecosystems policy and management.

2. The case study area

Uganda's land surface consists of approximately 13 per cent – about 30,000 km^2 – of wetland area (NEMA, 2007). Wetlands[1] are of large ecological, social and economic importance to the country. A significant part of the Ugandans settled in and around wetland areas and depend on the exploitation of their natural resources (Wasswa et al., 2013). However, wetland degradation is a widespread phenomenon in the country (Hartter and Ryan, 2010).

The present study focuses on the Rushebeya-Kanyabaha wetland, which is one of the larger wetlands in Kabale District in the southwest of Uganda (see Figure 1) (Glass, 2007). The Rushebeya-Kanyabaha wetland covers three sub-counties: Bukinda, Rwamucucu and Kashambya. The total intact size of the wetland covers nearly 5.0 to 5.5 km^2 and it is situated at 1,735 metres above sea level (Glass, 2007; Tweheyo et al., 2010). The ecosystem is a permanent wetland and its vegetation is dominated by papyrus (*Cyperus papyrus*) and southern cattail (*Typha domingensis*). While the wetland is largely intact, areas of agricultural encroachment and resource overextraction can be found (Glass, 2007).

[Figure 1 about here]

[1] Wetlands are defined by The Ramsar Convention on Wetlands of International Importance as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres" (Navid, 1989: 1004).

Kabale District is one of the most densely populated and highly cultivated rural districts of Uganda (Sanginga et al., 2007). It is characterized by its hilly landscape with wetlands or – in most cases – drained wetlands converted into agricultural land at the valley bottoms. Over 90% of the population lives in rural areas outside the central municipality, and with limited off-farm employment and income opportunities, the majority of the population relies primarily on subsistence farming for their livelihoods (Sanginga et al., 2005). The most common crops grown include sweet potatoes, Irish potatoes, sorghum, beans, peas, tobacco, cabbages and bananas (Glass, 2007).

Wetland uses include papyrus harvesting, beekeeping, fishing, water collection and using land (periodically or permanently) for farming. Although subsistence farming is an important source of food and income, wetlands also provide substantial alternative livelihood opportunities. The wetlands' papyrus and other grasses are used for waving mats, fishing baskets, carpets and other craftwork, which are often sold on local markets, as well as for as building materials used for thatching roofs and fences (Maclean et al., 2003). The Rushebeya-Kanyabaha wetland provides opportunities for hunting and for the collection of local medicinal products such as herbs, leaves, seeds and tree bark. It also provides a large range of indirect benefits that positively affect *inter alia* flood control, the microclimate, pollution, soil formation, nutrient cycling, and water quality (Langan and Farmer, 2014). In addition, the wetland provides habitat for, amongst others, waterbucks (*Kobus ellipsiprymnus*), sitatungas (*Tragelephus spekii*), crested cranes (*Balearica regulorum*), catfish (*Clarias gariepinus*), and mudfish (*Anguilla spp.*).

Historically, chieftains reigned over local law and allocation of land and natural resources in Uganda (Hartter and Ryan, 2010). During the politically unstable decades following independence from Great Britain in 1962, little attention was paid to wetland conservation. Wetlands were often used as wastelands; or were completely drained and converted to agricultural land (NEMA, 2001). Under president Yoweri Museveni, first steps towards wetland conservation were made (Hartter and Ryan, 2010). Nowadays, protection of wetlands is included in the Ugandan constitution: "Government or local government shall continue to hold in trust natural lakes, rivers, wetlands, forest reserves, game reserves, national parks and any land to be reserved for ecological and touristic purposes for the common good of all its citizens" (Langan and Farmer, 2014: 26). Following the devolution of natural resource management responsibilities to local governments in the 1990s, the regulation and control of wetlands lies in the hands of local councils (Hartter and Ryan, 2010). As stated in the constitution, these councils have to manage and control wetland use activities with both the community and the wetland in consideration (Bakeman and Iyango, 2001). Thus, communities are allowed by law to collect wetland resources for domestic use if this does not considerably harm the ecosystem (Bakeman and Iyango, 2001).

However, local governments encounter a dilemma between natural resource conservation and competing needs of different wetland users for natural resources to sustain and enhance their livelihoods. Local governments often also have general problems in applying national laws to the local context (Nkonya et al., 2005), or lack financial resources, knowledge or information to implement them (Banana et al., 2007). This has led to confusion about ownership, access and usage rights of wetland resources amongst local resource users. As a consequence of unchecked use, conversion and unenforced regulations, further degradation and land use change of wetlands throughout the country occurred (Banana et al., 2007; Hartter and Ryan, 2010). Hartter and Ryan (2010: 822) refer to these changes as “dramatic effects” of competing management regimes over a resource that is only limitedly available.

3. Methodology

3.1 Fuzzy cognitive map development

Individual and group developed fuzzy cognitive maps provide a representation of individual and shared knowledge (Gray et al., 2012a; Kafetzis et al., 2010; Özesmi and Özesmi, 2004). To reduce complexity and enable quantitative analysis, fuzzy cognitive maps are coded into adjacency matrices (see Figure 2 and Table 1), which take the following form: $A(D) = [a_{ij}]$. The structure of a respondent’s cognitive model is therefore determined by variables v_i listed on the vertical axis and variables v_j listed on the horizontal axis (Gray et al., 2012a). When a connection between two variables exists, it is coded in the square matrix (for an extensive explanation of coding cognitive maps into adjacency matrices see Özesmi and Özesmi (2004)).

[Figure 2 and Table 1 about here]

3.2 Fuzzy cognitive map analysis: structure

To assess the content and structure of fuzzy cognitive maps, the role and relative importance of each variable within the system is evaluated and the maps are characterized with the following metrics: centrality, complexity and density. There are three types of variables: transmitter variables [*T*], receiver variables [*R*], and ordinary variables [*O*] (Bougon et al., 1977; Eden et al., 1992; Gray et al., 2012a). The categorization is based on the value of a variable's outdegree [od(v_i)] and indegree [id(v_i)]. Outdegree is an indicator of a variable's cumulative strength of influence on other variables. Indegree shows the cumulative strength of variables entering the variable. Thus, it indicates how much a variable is influenced by other variables. Transmitter variables are forcing components (givens) with a significant influence over other variables, and consequently over the system. Receiver variables are the impacted components (ends): they have a high level of indegree and represent the end nodes of the system. Ordinary variables sit in between transmitter and receiver variables (means). (Bougon et al., 1977; Eden et al., 1992; Nyaki et al., 2014; Özesmi and Özesmi, 2004)

$$\mathrm{od}(v_i) = \sum_{k-1}^{N} \bar{a}_{ik} \tag{1}$$

$$\mathrm{id}(v_i) = \sum_{k-1}^{N} \bar{a}_{ki} \tag{2}$$

where (a_{ij}) is the cumulative strength exiting (equation 1) or entering (equation 2) the variable v_i, k is the index of summation and N is the number of variables.

The centrality [c_i], or total degree [td(v_i)] of a map measures the level of connectedness of a variable with the other variables (Bougon et al., 1977; Harary et al., 1965):

$$\mathrm{c}_i = \mathrm{td}(v_i) = \mathrm{od}(v_i) + \mathrm{id}(v_i) \tag{3}$$

Being end nodes, receiver variables indicate the possible outcomes of a system. Therefore, the share of total receiver variables in a map (R) with respect to the total number of transmitter variables (T) is used as an indicator of the complexity [com] of a map (Eden et al., 1992):

$$\text{com} = \frac{R}{T} \tag{4}$$

The density [D] of a fuzzy cognitive map describes how dense or sparse a map is and is thus a measure of connectivity (Hage and Harary, 1983).

$$D = \frac{C}{N^2} \tag{5}$$

where C is the number of connections and N^2 is the maximum number of connections possible between N variables.

3.3 Fuzzy cognitive map analysis: scenarios

Constructed fuzzy cognitive maps can be run as dynamic models to explore how the studied system develops under the perceptions of the respondents (Özesmi and Özesmi, 2004). First, a model's steady state is determined using the auto-associative neural network method (Reimann, 1998) to analyse whether a system settles into a basin of attraction (or not) (Dickerson and Kosko, 1994). This is done by calculating the system's (perceived) steady state using a map's adjacency matrix and a vector that assumes the initial state of all variables is one (I = 1), meaning that all of the variables in the map are fully activated. As such, the steady state indicates the basin of attraction in which the system tends to remain in a no-change scenario (Gray et al., 2015; Mouratiadou and Moran, 2007).

FCM simulations are often used for simulating a 'what-if' scenario or a policy option to observe the behaviour of the constructed models under different situations (Kontogianni et al. 2012; Stach and Kurgan, 2004). In the 'steady state' described above, also called no-management scenario, the variables equal one before running the model, and are then free to change in value during the iteration process. In the 'what-if' scenarios, one or more variables are 'clamped' (increased or decreased continually, using Kosko's (1986) clamping method) to a certain value during the iteration process, while the remaining variables are left to change until the system converges to different (or similar) set of equilibrium points (Gray et al., 2015; Özesmi and Özesmi, 2004). As such, scenario analysis exposes the perceived differences in the system and its functioning between the no-management scenario and the new system state of the modelled scenario.

3.4 Data and application

Primary data for this study were collected through in-depth interviews with local stakeholders in several villages within Rwamucucu sub-county, which accounts for 50% of the Rushebeya-Kanyabaha wetland and is located in the middle part (Glass, 2007). We followed a systematic stratified sampling approach. Papyrus harvesters, beekeepers, fishermen, farmers, and wetland non-users were selected a priori as relevant stakeholders based on their main wetland extraction activity, as previously identified in the literature (e.g. Bikangaga et al., 2007; van Dam et al., 2011; Langan and Farmer, 2014). In addition, we included local government officials as a separate stakeholder group to gain an understanding of wetland functioning from a government perspective. In the absence of available official data that could have been used to establish a sampling frame for each stakeholder group, lists of relevant stakeholders for each group were identified with the help of a well-respected local leader. In response to the many cognitive maps that mentioned ‘hunters’ and ‘hunting’ as distinct and important variables within the wetland system during the early fieldwork period, ‘hunters’ were added as another stakeholder group, following the same sampling procedure as above. Our sample is not designated to be representative of the adult population in Rwamucucu sub-county, but instead aims to capture a diversity of wetland stakeholders habituating in the area surrounding the wetland. The interviews took place during May and June 2014 and map collection took between 25 and 65 minutes. The average age of the respondents was 45 years. Accumulation curves of new variables showed that the sample size was sufficiently large, with the number of new variables rapidly decreasing from the 25th map onwards and stabilizing at the 33th interview (Özesmi and Özesmi, 2004).

In-depth interviews followed a common structure based on the main steps suggested by Özesmi and Özesmi (2004). After explaining the methodology via an unrelated example of a FCM, respondents listed all concepts (variables) they associate with the Rushebeya-Kanyabaha wetland ecosystem in an open-ended manner. Participants were free to include any concept they considered relevant, and were given sufficient time to contemplate (Christen et al., 2015). This was followed by mapping the relationships between those variables. In line with Gray et al. (2013), the relationships could be described as low, medium or strong (positive or negative) resulting in the following signs: ---; --; -; 0; +; ++; +++, where --- is -0.75, -- is -0.5, - is -0.25, no relationship is 0, + is 0.25, ++ is 0.5 and +++ equals 0.75. Reciprocal causal relationships (feedback loops) were allowed.

Using matrix addition, the individual cognitive maps were combined into seven stakeholder group maps (Özesmi and Özesmi, 2004). Each stakeholder map represents the combined perceptions of a stakeholder group about the wetland's functioning. In the process of combining individual maps, each individual map was given an equal weight. In the same manner, one 'community' map was constructed by aggregating the seven stakeholder maps. Afterwards, in line with Gray et al. (2012a), Özesmi and Özesmi (2004) and Zhang et al. (2013), qualitative aggregation was used to subjectively combine the variables into 13 categories – aggregated variables – to ease comparison and analysis. For the graph theory indices and scenario analysis the Excel-based programme FCMapper (Bachhofer and Wildenberg, 2011) was used. FCM software Mental Modeler (Gray et al., 2013) was used to digitize the community map and the group-developed map.

In addition to the individual maps, and in order to gain an understanding of shared (consensus) knowledge and the role of group dynamics, one group-developed map was obtained through a group interview with two papyrus harvesters, one beekeeper, one fisherman, two wetland farmers, and one hunter, all of whom were male. Two participants were randomly selected from each stakeholder list, after which a meeting was set up. The group map was obtained in approximately 85 minutes and the procedure was the same as described above.

3.5 Scenario Analysis

The aggregated stakeholder maps are used to explore three scenarios. The first scenario models system anticipation to wetland conservation. Because wetlands provide important ecological and social functions such as sediment retention, biodiversity maintenance, food and water provision, and are in addition an effective carbon sink (Dugan, 1990; McCartney et al., 2004), long-term conservation of wetlands in good ecological condition may be an important management goal. Note that wetland conservation in this context does not imply to forgo wetland utilisation, as recognised in the Ramsar Convention (Ramsar Convention Bureau, 1997). In relation to the Rushebeya-Kanyabaha wetland this means conservation of the wetland ecosystem, while at the same time allowing for the extraction of wetland resources in a way that leaves the ecosystem largely unharmed.

The second scenario is denoted as wetland cultivation. Many of the world's remaining wetlands are threatened by drainage and subsequent cultivation (Dixon and Wood, 2003). In Uganda, as well as in many other developing countries, wetland cultivation can considerably contribute to communities' livelihoods. Wetlands provide high levels of soil fertility, higher crop yields and allow for a wider range of crops to be cultivated compared to dry lands (Masiyandima et al., 2004). Wetland cultivation can also be understood as a strategy to cope with production risks associated with low levels of food production during dry seasons and droughts (Dixon and Wood, 2003). An increase in agricultural activity on the wetlands is a therefore a future scenario that merits consideration.

The third scenario investigates stakeholders' perception of system anticipation to changes to laws and rules that govern access to wetlands and their use. The creation of additional formal laws and rules regarding wetland use and management, and their local enforcement, may be an important policy option to pursue in an effort to protect the wetland ecosystem.

4. Results

4.1 Individual fuzzy cognitive maps: Descriptive statistics

The obtained individual fuzzy cognitive maps account for 183 distinct variables associated with the Rushebeya-Kanyabaha wetland. The mean number (±SD) of variables in the 40 maps is 22.35 (± 6.16), while the mean number of connections is 29.03 (± 9.67).

Individual cognitive maps are assessed based on a number of graph theory indices (see Table 2). Visual inspection suggests that beekeepers and government officials' maps have a higher number of total and receiver variables. In addition, government officials and wetland non-users show a higher complexity mean, indicating a high level of perceived end nodes in the system relative to the number of transmitter variables. However, using a one-sided ANOVA, the only difference found to be statistically significant amongst all stakeholder groups is the number of connections (*C*), with beekeepers and government officials perceiving an above average level of connectedness between variables that influence the system's functioning.

[Table 2 about here]

Table 3 provides an overview of the most frequently mentioned variables per stakeholder group. There are commonalities in the most frequently mentioned variables across stakeholder groups. All groups frequently refer to ‘papyrus’ and ‘mudfish’. While ‘cultivation’, ‘grasses’ and ‘mats’ are mentioned by most groups, other variables such as ‘beehives’, ‘building materials’, ‘medicine’ or ‘hunting’ appear to be more prevalent within particular stakeholder groups. The results indicate that there is a strong focus on the material benefits derived from the wetland. Non-material benefits, as well as detrimental effects of the wetland on people and the impacts of people (whether positive or negative) on the wetland are less prominent.

[Table 3 about here]

4.2. Aggregated stakeholder maps

In order to ease analysis of the perceived structure of the wetland ecosystem, the individual fuzzy cognitive maps are combined into stakeholder maps and then simplified through qualitative aggregation. The 183 variables were aggregated into 13 categories: (1) agricultural production, (2) beekeeping, (3) climate, (4) environmental problems, (5) fishing, (6) health and safety, (7) hunting, (8) laws and rules on wetland use, (9) livelihood, (10) social forces, (11) water collection and water use, (12) wetland ecosystem health, and (13) wetland products (see Appendix A for variable aggregation list).

Levels of centrality, indegree and outdegree are compared to examine how certain variables act in relation to others (see Figure 3 for centrality levels of variables for the different stakeholder groups). The Rushebeya-Kanyabaha wetland is perceived to be strongly associated with peoples’ livelihoods through a diverse range of activities. There is a broad agreement among stakeholders regarding the variables that are most central to the system, those that have high impacts on other variables, and those that are outcomes of the system. Overall, ‘wetland ecosystem health’, ‘wetland products’, ‘environmental problems’ and ‘livelihood’ are the most central variables.

‘Wetland ecosystem health’, which includes the variables ‘biodiversity’, ‘habitats’ and ‘water quality’, amongst others, is the most central variable for all stakeholder groups. This variable is perceived as an important forcing component with strong influences on other variables, such as ‘wetland products’, ‘livelihood’, and ‘water collection and water use’. Indegree levels are somewhat lower for all stakeholder group maps but show that ‘wetland ecosystem health’ is also highly dependent upon other variables, for example on ‘environmental problems’ and ‘hunting’. Similarly, the variable category ‘wetland products’ is a central variable for all stakeholder groups.

‘Livelihood’ is also perceived as highly central within the wetland system. It has a very low level of outdegree in all stakeholder maps, indicating that it is mainly perceived as an end node or possible outcome of the system, being influenced by other concepts. The degree to which this variable is influenced by other variables differs among the stakeholders. For example, government officials and beekeepers perceive the variable ‘livelihood’ to be highly influenced by ‘wetland products’, ‘fishing’, ‘beekeeping’, and ‘wetland ecosystem health’. In contrast, hunters and wetland non-users indicate a relatively low cumulative strength of variables entering ‘livelihood’, which may be explained by the relatively low contribution of wetland products to their livelihoods.

[Figure 3 about here]

For all stakeholder groups except farmers, ‘environmental problems’, such as water pollution, wetland draining and over-extraction, is among the four most central variables, suggesting that this variable is strongly connected to other variables in the wetland system as both a driving and a dependent variable. Interestingly, levels of centrality, indegree and outdegree are much lower for farmers indicating that they perceive environmental problems to be less relevant within the system than other stakeholder groups.

‘Laws and rules on wetland use’, on the other hand, does not seem to be a very central variable for most stakeholder groups. Although most respondents view the variable as a forcing component to – for example – reduce ‘environmental problems’, ‘hunting’ or ‘agricultural production’, none of the stakeholder groups regard the variable as one of high centrality. However, interesting differences exist for government officials and farmers. Government officials perceive ‘laws and rules on wetland use’ as a relatively central concept compared to other stakeholder groups, which may indicate that government officials believe laws and rules on wetland use to be more effective for wetland conservation than the other stakeholder groups. Farmers assign the lowest level of outdegree to ‘laws and rules on wetland use’.

They perceive laws and rules on wetland use to have limited impact on the health of the wetland's ecosystem, which may possibly be explained by the fact that (historic) encroachment on the wetland to establish farming activities has not been challenged or penalised.

4.3 'Community' and group-developed fuzzy cognitive maps

The seven stakeholder maps were combined into one community map in the same way the individual maps were combined into stakeholder maps previously. The aggregated community map in Figure 4 shows 34 out of the 73 strongest connections in an attempt to make the map more readable. The cut-off values that were used for this are 0.01 and -0.01, respectively. Figure 5 portrays the aggregated version of the group-developed map obtained through a group-interview and shows all the connections.

In the aggregation process of individual maps, opposing connections (i.e. opposite signs are used to indicate a relationship) decrease the strength of the concerning relationship, while agreement on a connection reinforces a causal relationship, hereby creating a community (or stakeholder) consensus map. A group-developed map is also an external representation of the knowledge shared among participants, but additionally reflects the outcome of social interaction (Gray et al., 2014). In the process of creating a group map, individual knowledge of a system is socially negotiated, which results in a consensus not only based upon perceptions and knowledge, but also on personalities, relationships, and levels of equality within the group (Gray et al., 2014). A group-developed map does not necessarily represent better how the system operates. However, a group map can offer interesting insights into the dynamics that could be observed at the landscape level and that might be difficult to capture through one single eliciting method. While the individual stakeholder map approach provides better insights into differences in perceptions and the areas of opposing interests, the process of a group interview is much more likely to encompass social learning among the participants, and may thus be a worthwhile approach for knowledge transfer activities and stakeholder alignment.

[Figure 4 and Figure 5 about here]

Visual comparison of the community map and the group-developed map suggests that the latter contains fewer connections between the variables. As such, the group-developed map shows a lower degree of interaction between variables in the system (Özesmi and Özesmi, 2004). This is in part caused by a lack of consensus between different contributors over the signs and strengths of certain relationships that are not included in the map due to disagreement. However, the maps show similar areas of shared knowledge. For example, both maps indicate a shared knowledge among respondents that 'wetland ecosystem health' has positive influences on, amongst others, 'livelihood', 'beekeeping', 'fishing', and 'water collection and use', but also show that 'wetland ecosystem health' is threatened by 'environmental problems' and 'hunting'.

There are also some evident differences between the two maps. In the group-developed map, no consensus was found between the participants on the influence of 'agricultural production' on 'wetland ecosystem health', whereas the community map shows a negative relationship. In addition, contrasting signs are assigned to the impact of 'wetland ecosystem health' on 'agricultural production'. This is caused by a different focus on the relationship between 'wetland ecosystem health' and 'agricultural production': participants involved in creating the group-developed map only mentioned the total area available for agricultural production (which decreases as wetland ecosystem health increases) as a measure of 'agricultural production'. Individual stakeholders, however, tended to focus on the beneficial impacts of the wetland on 'agricultural production', such as increased soil fertility resulting in higher agricultural production output.

5. Scenario analysis

The community map and the group-developed map have exposed the broad areas of shared knowledge amongst community members. While understanding shared community knowledge is important in explaining some aspects of system functioning, it is equally relevant to expose differences in perceptions and opposing interests that may underlie (potential) wetland degradation and land use change. Using neural network theory, the aggregated stakeholder maps are used to gain insight into the similarities and differences in perceived dynamic functioning of the wetland system. We use the seven stakeholder models to run three different scenarios of the wetland system, which are then compared to the model's steady state (i.e. no-change scenario). The results thus portray inferences about the shared expectations and predictions within a stakeholder group regarding a simulated change in the system.

The results suggest that all seven stakeholder models run into a steady state after less than 20 iterations. This means that chaotic behaviour of the perceived system is not an issue. Appendix B shows the steady state of the different stakeholder maps.

5.1 Scenario 1: Wetland conservation

To explore how the different stakeholder groups perceive the relative changes in the functioning of the wetland system under a wetland conservation scenario, we activated the category ‘wetland ecosystem health’ at a level of one throughout all iterations when running the stakeholder models. Figure 6 presents the relative changes between the steady state and the wetland conservation scenario.

[Figure 6 about here]

The results indicate mostly positive changes for the variables. Interestingly, all stakeholder groups indicate that ‘beekeeping’, ‘fishing’, ‘water collection’, and collection of other ‘wetland products’ increase for a wetland conservation scenario. These findings indicate a shared perception that wetland conservation and livelihood gains can be achieved simultaneously. The largest increase in the system is found for ‘wetland products’, which can be explained by the fact that wetland products are extracted from the wetland. Therefore, an increase in wetland ecosystem health would result in an increase in (to be) harvested wetland products. ‘Fishing’, ‘beekeeping’, and ‘water collection and use’ also show relatively large positive changes associated with a wetland conservation scenario.

In line with the above, one evident change is the positive increase in ‘livelihood’ perceived by all stakeholder groups. The relative impact is slightly lower for hunters and wetland non-users, who are overall less dependent on the wetland ecosystem for their livelihoods. On the other hand, most stakeholder groups also associate an increase in ‘wetland ecosystem health’ with an overall decrease in ‘health and safety’. This decrease is related to health risks associated with the wetland, such as the risk of drowning, wild animal-related health risks, or incidence of mosquitoes and other insects that increase the risk of infection with malaria or other diseases. These negative impacts are partly offset by health and safety benefits associated with the wetland, including medicinal uses of some wetland products, such as honey.

In addition, all stakeholder groups except wetland non-users perceive the wetland to have a positive impact on ‘agricultural production’. Stakeholder perceptions indicate that the wetland provides important benefits to agriculture, especially during dry seasons or droughts when the upland soils are less suitable for food production. Wetland soils are very fertile and enable for a wider range of crops and higher crop yields (Masiyandima et al., 2004). In addition, wetland degradation causes large decreases in soil fertility, which in turn reduces agricultural output (Schuyt, 2005). Contrary to the other six stakeholder groups, wetland non-users perceive a negative change for ‘agricultural production’ associated with an increase in ‘wetland ecosystem health’. This association is likely caused by a stronger focus on the potential area used for agricultural production that is lost if the wetland area increases relative to the emphasis placed on changes in soil and crop productivity resulting from an increase in ‘wetland ecosystem health’.

The findings confirm that the seven stakeholder groups have very similar perceptions of the functioning of the system. All stakeholder groups perceive a wetland conservation scenario to be largely beneficial for the community, although there are some perceived negative implications for ‘health and safety’ and differences on the distribution of benefits.

5.2 Scenario 2: Wetland cultivation

In the second scenario, an increase in wetland cultivation is modelled, where the aggregated variable ‘agricultural production’ was continually increased to a value of one during the iteration process. The results indicate perceived changes in ‘livelihood’ and ‘wetland ecosystem health’, but do not suggest notable changes for the other categories (see Figure 7).

The shared perception among all stakeholder groups is that an increase in ‘agricultural production’ in the system causes the wetland ecosystem to degrade compared to the steady state. Although agreeing in the direction of the relationship, farmers perceive only very little degradation resulting from increased ‘agricultural production’ compared to the other six stakeholder groups, who perceive much larger relative changes in the health of the wetland ecosystem. Similarly, all stakeholder groups except farmers also agree on a minor decrease in ‘wetland products’.

[Figure 7 about here]

It is interesting to compare the perceptions of stakeholder groups in terms of livelihood benefits obtained across the wetland conservation and the wetland cultivation scenarios. Farmers and government officials perceive wetland cultivation to yield more livelihood gains than wetland conservation, while all other stakeholder groups associate wetland conservation with higher livelihood benefits. Hunters and wetland non-users even associate an increase in 'agricultural production' with a decrease in 'livelihood'.

5.3 Scenario 3: Enforcement of laws and rules

From the aggregated community map and group map it can be seen that for a wetland conservation scenario 'environmental problems', 'hunting', and 'agricultural production' are the main factors driving wetland degradation. 'Laws and rules on wetland use' is the one perceived factor that reduces all three. In scenario 3, we explore the perceived impact of increased local enforcement of new and existing rules on wetland use and management. 'Laws and rules on wetland use' was set equal to one for all iterations, and is to remain high while other aggregated variables change in reaction to the clamped variable. Figure 8 provides a representation of the relative changes from the steady state of the stakeholder models when enforcement of laws and rules on wetland use is enhanced.

[Figure 8 about here]

All stakeholder models converge to negative changes for the variable 'agricultural production'. In addition, all but wetland non-users agree on a decrease in 'environmental problems' compared to the no-change scenario, and all stakeholder groups but farmers agree on the positive impact on the health of the ecosystem. Government officials and beekeepers perceive a decrease in 'hunting'. The changes are, however, relatively small in magnitude compared to some of the changes in the first two scenarios, which is likely be caused by low levels of outdegree and connectedness of the variable, as reported in section 4.2.

6. Discussion

The results show that the Rushebeya-Kanyabaha wetland is highly beneficial in supporting the local community in the area surrounding the wetland. As indicated by the respondents, the wetland provides a large diversity of livelihood activities such as fishing, papyrus and grass harvesting and wetland cultivation. Despite its importance, local stakeholders perceive several factors threatening the health of the wetland ecosystem. In line with Barbier et al. (1997) and Schuyt (2005), the results indicate that the largest threats for the wetland's sustainability are human activities. These human-induced pressures, including wetland encroachment and cultivation, burning and over-extraction of wetland resources, provide indications of potential resource use issues arising from different interests and views on how to manage the wetland. While some of the differences in perceived wetland functioning between the stakeholder groups arise from their main wetland use – e.g. farmers perceive 'agricultural production' more central to the system, while beekeepers place 'beekeeping' as more central compared to other stakeholder groups – other differences require a more extensive explanation.

Farmers' perceptions are found to diverge most from the other stakeholder groups with several perception indicators pointing towards different results. Farmers have different perceptions on the centrality of 'environmental problems' and 'laws and rules on wetland use', which they both perceive to be less connected to other variables in the system. This is likely to be caused by the conflict of interest that arises between permanent wetland cultivation and wetland conservation. Government officials also perceive several factors within the wetland's system differently compared to the other stakeholder groups. They have a relatively strong focus on 'livelihood' and 'environmental problems'. In addition, they regard 'laws and rules on wetland use' as a relatively central variable compared to the other stakeholder groups. Wetland non-users, who do not rely as much on wetland products or services and whose livelihoods are thus likely to be less impacted by any changes occurring in the ecosystem, also show some deviant perceptions. Wetland non-users assign a higher centrality value to the category 'health and safety'. Because wetland non-users do not benefit as much from the wetland as other groups do, they place a higher focus on the dis-benefits or negative impacts arising from wetland compared to other stakeholders.

The results of the scenario analysis also portray these opposing interests between stakeholders. The largest difference in perceptions can be found between farmers and the other stakeholder groups. While the combined community map of all stakeholder groups indicates that wetland conservation is the most optimal wetland scenario, farmers associate the largest perceived increase in 'livelihood' with increased agricultural production coming from wetland cultivation. Government officials also perceived increases in 'livelihood' to be larger in the second scenario than in the first. This divide in perceptions between farmers, government officials and the other stakeholder groups regarding the (future) state of the system might contribute to the increasing degradation of the Rushebeya-Kanyabaha wetland. This may also apply to other Ugandan wetlands with similar resource user groups and governance structures. Also indicated by stakeholder maps' steady state, a negative change in 'wetland ecosystem health' is perceived as one of the largest issues in the system when no changes occur in the system's resource management (see Appendix B).

The comparison between the community maps, obtained by aggregating individual stakeholders' maps, and the group developed map shows that similar shared knowledge is found using both approaches. However, the group developed map did not reveal some areas where no consensus is found between stakeholders and therefore might not uncover some important drivers of wetland use and management.

Wetlands provide products and services that can be of high value to local communities, however, the quantity of these products and services is limited. In consequence, competition may arise between resource users. For example, what a hunter gains in additional wildlife catch by burning a small part of the wetland in order to direct the animals towards him may come at the loss of a papyrus harvester's harvest. While this example describes a distributional issue of who receives which wetland benefits with the overall wetland productivity staying approximately the same, competing resource uses can also have problematic effects on the health of the ecosystem itself. How to manage the trade-offs between nature conservation and economic development is therefore a key challenge to sustainable development. This paper shows that in the case of the Rushebeya-Kanyabaha wetland, natural resource conservation and sustained livelihoods are perceived by most stakeholders as being convergent rather than divergent goals. The local community perceives the wetland to be important for their livelihoods. Being openly accessible, the wetland provides free products that are often especially important for the poorer segment of the community who lack the resources to engage in other income generating activities (Bikangaga et al., 2007; Dasgupta, 2002; Dixon and Wood, 2003). The results of the scenario analysis indicate that all stakeholder groups associate wetland conservation with positive impacts on wetland products with limited perceived negative impacts. Therefore, efforts towards wetland conservation that permit its utilisation at levels that leave the wetland largely unharmed are likely to produce more equitable outcomes than efforts to increase agricultural production, which is largely perceived detrimental to wetland ecosystem health and wetland products.

Our results are also in line with Bakema and Iyango (2001) and Hartter and Ryan's (2010) conclusions that Ugandan wetlands cannot merely be regulated through central government legislation. Simulating an increased enforcement of 'laws and rules on wetland use' (scenario 3) shows that a mere increase in the effort to enforce laws and rules on wetland use will not have many notable implications. Minor decreases in 'agricultural production' and 'environmental problems', and a slight increase in 'wetland ecosystem health' can be pointed out. This limited perceived impact of increased law enforcement together with a low perceived centrality of the variable 'laws and rules on wetland use', suggests that a nested approach framing locally devised and tailored governance mechanisms within the national regulatory frameworks could contribute to better wetland management. Consequently, a nested approach combining both top-down and bottom-up approaches may be more suitable for sustainable natural resource management that simultaneously meets human needs and maintains a functioning ecosystem. Initiatives and institutions at the grassroots level enable local stakeholder involvement in management and policy processes, causing engagement and a feeling that they benefit from the decisions that are made (Bikaako-Kajura, 2002; Richardson, 1993). As is argued by Heikkila and Gerlak (2005), common understanding across different stakeholders is important for collective action originating from the grassroots level. Shared knowledge has been associated with trust and cooperation, shaping the interaction between individuals and groups (Gray et al., 2012b). The different stakeholder maps show many areas of consensus and common understanding of the wetland system and stakeholders show awareness of the impacts of their actions on other stakeholders. However, as described above, there are several important opposing interests and perceptions between stakeholder groups, which are likely to create (potential) obstacles for collective action initiatives.

Bottom-up approaches may be designed as an adaptive governance process. There is an increasing interest in adaptive governance of natural resources (Chaffin et al., 2014), which is characterised by "flexible and learning-based collaborations and decision-making processes involving both state and non-state actors, often at multiple levels, with the aim to adaptively negotiate and coordinate management" (Schultz et al., 2015: 7369). Adaptive management, which is a key component of adaptive governance, benefits from the generation of knowledge and understanding of socio-ecological systems and their dynamics, and FCM can be an important starting point for the identification of common and diverting interests and perceptions as a basis for negotiating and developing common goals and appropriate governance structures. Progress has been made in using spatial data to monitor land cover change in papyrus wetlands as an important component of wetland policies (Jacob et al., 2014). FCM may complement the sequential learning and adaptation processes characterising adaptive management. This can include understanding how perceptions of a system's functioning change over time and as a consequence of management action.

Insufficient knowledge of the functions and benefits of wetlands is often mentioned as one of the most important factors that underlie natural resource degradation (e.g. Bakema and Iyango, 2001; Turner et al., 2000). The results of this study show that local stakeholders strongly focus on wetland products. This is in line with findings of Hartter (2010), who finds that ecosystem goods are more frequently mentioned as perceived benefits from wetlands in and around Kibale National Park by the local population. In contrast, knowledge of the wetland's services, which affect *inter alia* water quality, flood control, the microclimate, nutrient cycling, and soil formation, and wetland attributes such as biodiversity, aesthetics, symbolic significance, or future options (e.g. future pharmaceutical use of wetland products) is less explicit. Despite overwhelming scientific evidence on the ecological importance of wetlands (e.g. Constanza et al., 1997; Moreno-Mateos et al., 2012; Turner et al., 2000), the local community's main rationale for managing the wetland sustainably appears to be direct use of the wetland for economic benefit. These results are in line with Luwum and Acuba (1998), who performed research on the importance of wetlands for local communities in Uganda and found that a large majority of the respondents mentioned wetland products and their accompanying economic value, while a much smaller percentage of the respondents mentioned wetland services and almost no-one referred to non-use values. Bakema and Iyango (2001) and Franco and Luiselli (2014) have similar findings for wetlands in Uganda and Italy, respectively. These results highlight temporal trade-offs between short-term use of wetlands and their long-term conservation.

7. Conclusion

Fuzzy cognitive mapping was applied to study the Rushebeya-Kanyabaha wetland in Uganda to (1) compare individual stakeholder perceptions and group knowledge of the wetland ecosystem, its use and the relationships between users; and to (2) simulate different wetland scenarios based on stakeholder perceptions. The findings demonstrate that FCM reveals important information for the development of environmental management strategies. For the majority of stakeholders, a wetland conservation scenario results in positive impacts on wetland products and livelihoods. Relative to other stakeholder groups, government officials' and especially farmers' perceptions suggest that an increase in agricultural production through increased wetland cultivation has considerable positive impacts on livelihoods with no or limited negative impacts on the health of the wetland ecosystem and the products derived from it. This diverging interest is likely to threaten the future sustainability of the wetland and therefore deserves particular attention by decision makers. Using stakeholders' perceptions, this study shows that development of shared understanding of wetland management benefits from a bottom-up approach. A nested approach that integrates these bottom-up approaches within top-down regulatory frameworks, together with increasing awareness of and knowledge on the ecological values of the wetland, would be the preferred management approach to realizing sustainable wetland utilization. The study also illustrates how FCM can shed light on adaptive management processes by enabling social learning and providing opportunities for feedback. In this regard, FCM could be combined with other deliberative methods to define scenarios, explore related governance systems and understand trade-offs between different goals and management approaches and their implications in terms of equity and well-being. Finally, our study points out to the need to further understand differences between individual and group developed FCMs. While group developed maps could foster social learning, our research shows that much knowledge about the social-ecological system may be left out due to the divergence in opinions, power dynamics, social rules, etc. In this regard, individual elicitation of maps might be better fitted to find consensus and divergent views that may point at potential challenges over the studied resource.

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APPENDIX A

Table A.1 Overview of categories: Variable aggregation list

Category	Variable	Sign
Agricultural production	Area available for agriculture	+
	Beans	+
	Cabbages	+
	Carrots	+
	Crops	+
	Cultivation	+
	Encroachment	+
	Fruits	+
	Irish potatoes	+
	Land available for agriculture	+
	Livestock	+
	Livestock grazing	+
	Maize	+
	Manure	+
	Potatoes	+
	Sorghum	+
	Sugar canes	+
	Sweet potatoes	+
	Tea crops	+
	Tea production	+
	Tobacco	+
	Vegetables	+
Beekeeping	Beehives	+
	Beekeeping	+
	Bees	+
	Honey	+
	Improved beehives	+
	Lack of wax supply	-
	Nectar	+
Climate	Bad weather	-
	Climate	+
	Climate change	-
	Climate modification	+
	Clouds	+
	Drought	-
	Rainfall	+
	Rainfall formation	+
	Temperature	+
Environmental problems	Burning	+
	Dead animals	+
	Dead people	+
	Deforestation	+
	Draining	+
	Eucalyptus trees	+
	Flooding	+
	Noise pollution	+
	Over-extraction	+
	Papyrus over-extraction	+
	Pests	+
	Population growth	+
	Soil erosion	+
	Species extinction	+
	Unwanted grasses	+
	Upland soil erosion	+
	Water pollution	+

Fishing	Bait production	+
	Fish	+
	Fish extraction	+
	Fish farming	+
	Fish ponds	+
	Fishermen	+
	Fishing	+
	Mudfish	+
Health and safety	Child mortality	-
	Diseases	-
	Drowning	-
	Health	+
	Liver flukes	-
	Malaria	-
	Mosquitoes	-
	Nagana	-
	Medicine	+
	Safety	+
	Sleeping sickness	-
	Tsetse flies	-
	Typhoid	-
Hunting	Hunters	+
	Hunting	+
	Skin	+
Laws and rules on wetland use	Demarcation	+
	Fencing	+
	Government	+
	Laws	+
	NEMA	+
	Rules on wetland use	+
	Spray	+
	Wetland management committee	+
Livelihood	Boats	+
	Bridge	+
	Clothes	+
	Clothing	+
	Dog food	+
	Domestic use	+
	Education	+
	Food	+
	Food for dogs	+
	Hiding place for thieves	-
	Hunger	-
	Income	+
	Jobs	+
	Livelihood	+
	Livestock food	+
	Market	+
	Meat	+
	Own use	+
	Savings	+
	Tourism	+
	Transport	+
Social forces	Alcohol	-
	Community	+
	Damage of beehives	-
	Intruders	-
	Study	+
	Taps	+
	WorldVision NGO	+
Water collection and water use	Bathing	+

	Cattle watering	+
	Cooking	+
	Drinking	+
	Irrigation	+
	Livestock watering	+
	Washing	+
	Washing (motor) cycles	+
	Water collection	+
Wetland ecosystem health	Aesthetics	+
	Afforestation	+
	Biodiversity	+
	Birds	+
	Conservation	+
	Crested cranes	+
	Foxes	+
	Frogs	+
	Geese	+
	Hyenas	+
	Monkeys	+
	Nature	+
	Nature preservation	+
	Open resource	+
	Otters	+
	Rats	+
	Snakes	+
	Soil fertility	+
	Species habitat	+
	Tree growing	+
	Trees	+
	Upland soils	+
	Water	+
	Water availability	+
	Water level	+
	Water organisms	+
	Water purification	+
	Water quality	+
	Waterbucks	+
	Wetland	+
	Wild animals	+
	Wild cats	+
Wetland products	Baskets	+
	Bedding	+
	Bricks	+
	Building materials	+
	Charcoal	+
	Clay	+
	Crafts	+
	Decoration	+
	Dust	+
	Firewood	+
	Fishing baskets	+
	Grass flowers	+
	Grasses	+
	Hats	+
	Matrasses	+
	Mats	+
	Paper	+
	Papyrus	+
	Papyrus leaves	+
	Pillows and matrasses	+
	Plants	+

Plants for tooth brushing	+
Pots	+
Ropes	+
School purposes	+
Shed provision	+
Thatching	+
Timber	+

APPENDIX B

Table B.1 Steady state stakeholder maps

	Papyrus harvesters	Farmers	Fishermen	Beekeepers	Government officials	Hunters	Wetland non-users
Agricultural production	0,505	0,555	0,525	0,522	0,533	0,510	0,480
Beekeeping	0,513	0,500	0,500	0,516	0,505	0,513	0,500
Climate	0,505	0,525	0,501	0,500	0,507	0,500	0,515
Environmental problems	0,505	0,513	0,511	0,530	0,543	0,494	0,535
Fishing	0,502	0,542	0,528	0,546	0,518	0,564	0,519
Health and safety	0,493	0,487	0,474	0,476	0,501	0,500	0,427
Hunting	0,502	0,507	0,511	0,513	0,514	0,500	0,500
Laws and rules on wetland use	0,505	0,500	0,500	0,503	0,511	0,500	0,500
Livelihood	0,688	0,631	0,603	0,597	0,656	0,543	0,527
Social forces	0,500	0,498	0,496	0,498	0,514	0,500	0,500
Water collection and water use	0,512	0,510	0,516	0,517	0,525	0,500	0,524
Wetland ecosystem health	0,466	0,493	0,420	0,421	0,404	0,416	0,469
Wetland products	0,561	0,575	0,548	0,532	0,544	0,573	0,579

Note: the steady state provides an indication of the ranking of each variable in relation to the other variables based on how the system is perceived (Özesmi and Özesmi, 2004). From the steady states, it can be concluded that decreasing wetland ecosystem health is perceived as the largest problem in a no-change scenario.

APPENDIX C

Table C.1 Centrality levels per stakeholder group

	Papyrus har-vesters	Farmers	Fisher-men	Bee-keepers	Govern-ment officials	Hunters	Non-wetland users
Agricultural production	0.50	1.28	0.62	0.60	1.05	0.49	0.54
Beekeeping	0.31	0.12	0.00	0.68	0.15	0.37	0.00
Climate	0.15	0.61	0.32	0.04	0.25	0.00	0.41
Environmenta l problems	0.68	0.41	0.94	1.39	1.18	0.99	0.66
Fishing	0.48	0.53	0.39	0.70	0.71	0.97	0.29
Health and safety	0.06	0.28	0.35	0.39	0.19	0.00	0.60
Hunting	0.12	0.12	0.50	0.58	0.60	0.12	0.04
Laws and rules on wetland use	0.17	0.03	0.14	0.19	0.31	0.19	0.12
Livelihood	1.61	0.99	0.89	0.78	1.33	0.30	0.37
Social forces	0.04	0.06	0.03	0.15	0.23	0.00	0.00
Water collection and water use	0.21	0.11	0.19	0.23	0.39	0.00	0.21
Wetland ecosystem health	1.69	2.22	2.55	2.78	2.96	2.17	2.19
Wetland products	1.58	0.76	1.19	1.06	1.03	0.95	0.77

Table 1 Adjacency matrix coded from the fuzzy cognitive map in Figure 2

	A	B	C
A	0	0.25	0
B	0.75	0	-0.5
C	0	0	0

Table 2 Graph theory indices: mean and standard deviation by stakeholder group

Stakeholder group	Papyrus har-vesters	Bee-keepers	Fishe-rmen	Farmers	Govern-ment officials	Wetland non-users	Hunters
No. of maps	6	6	8	9	6	3	2
No. of variables (*N*)	20.00 ±3.03	26.83 ±11.05	21.75 ±5.57	20.89 ±4.68	25.67 ±2.67	19.67 ±3.21	19.00 ±2.12
No. of transmitter variables (*T*)	2.33 ±1.03	3.50 ±3.33	3.50 ±2.07	2.44 ±1.24	2.67 ±2.16	2.00 ±1.00	4.50 ±2.12
No. of receiver variables (*R*)	5.83 ±1.83	9.67 ±4.93	7.13 ±2.59	8.78 ±2.99	11.50 ±2.74	8.67 ±3.06	5.50 ±2.12
No. of ordinary variables (*O*)	11.50 ±3.56	13.83 ±5.98	11.13 ±4.12	9.44 ±3.57	11.33 ±5.05	8.67 ±3.06	8.50 ±2.12
No. of connections (*C*) *****	27.17 ±6.08	37.00 ±15.24	28.88 ±9.52	25.89 ±6.57	33.17 ±7.96	21.00 ±5.29	25.00 ±11.31
Complexity (com)	3.11 ±1.88	4.42 ±2.63	2.88 ±2.18	3.28 ±1.71	5.92 ±4.92	6.00 ±5.29	1.25 ±0.12
Density (*D*)	0.069 ±0.013	0.059 ±0.023	0.063 ±0.015	0.062 ±0.015	0.051 ±0.008	0.054 ±0.006	0.079 ±0.009

* Statistically significant differences in indices among stakeholder groups (P<0.05)

Table 3 Most frequently mentioned variables by stakeholder group

	Papyrus harvesters	Bee-keepers	Fishermen	Farmers	Government officials	Wetland non-users	Hunters
Papyrus	X	X	X	X	X	X	X
Mudfish	X	X	X	X	X	X	X
Beehives		X					
Building material	X						
Burning		X					X
Cultivation		X	X	X	X		X
Grasses	X		X	X	X	X	X
Hunting					X		
Income	X						
Market	X						
Mats	X			X	X	X	X
Medicine		X					
Thatching					X	X	
Waterbucks					X		X

Note: 'X' indicates the variables that are mentioned by at least 75 per cent of the individuals in a particular stakeholder group. The variable 'wetland' was provided to all respondents at the start of the interview, and is thus included in every individual's map.

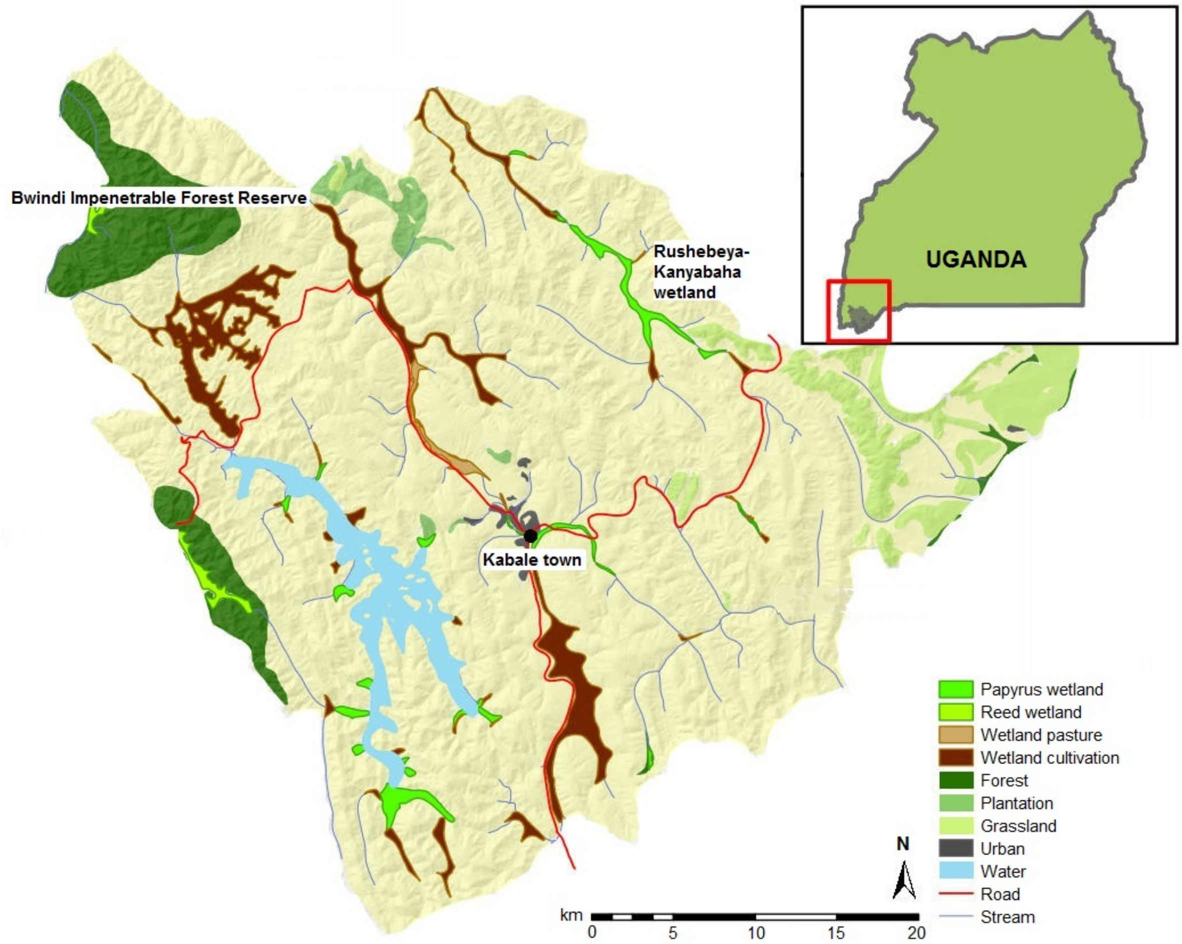

Figure 1 Map of the Kabale District and the case study area. The Rushebeya-Kanyabaha wetland area is located in the north-east of the District and is indicated on the map. Source: Langan et al. (2015).

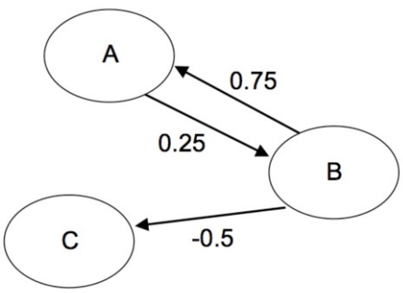

Figure 2 Example of a fuzzy cognitive map

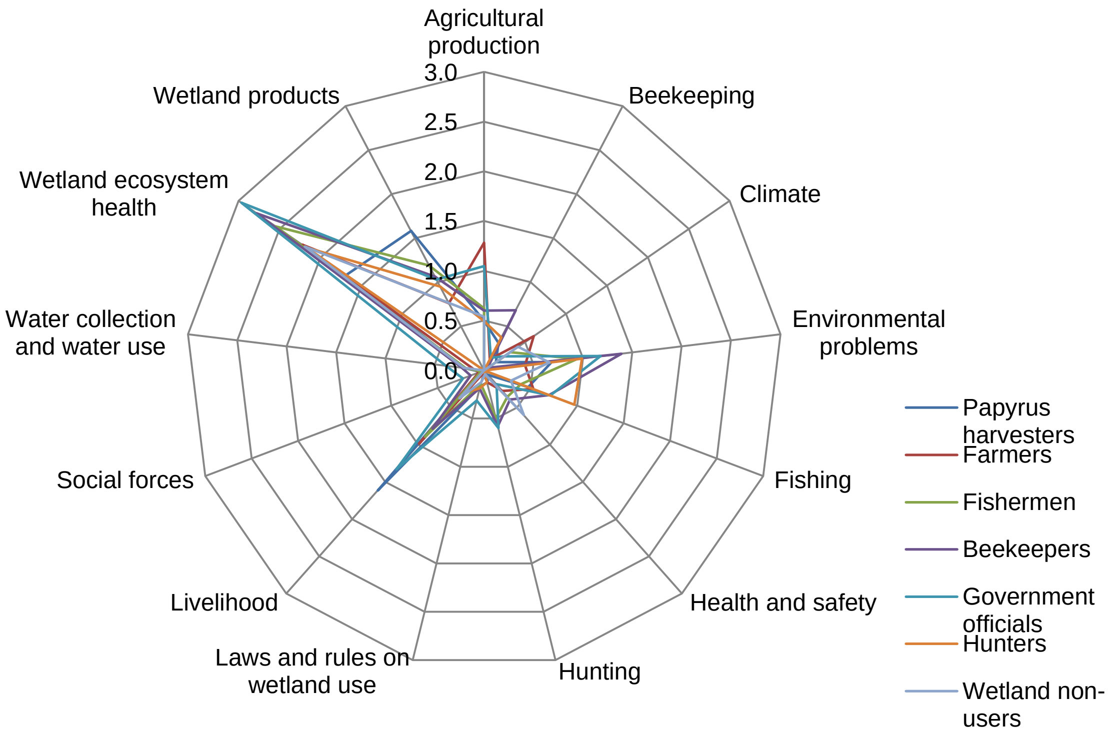

Figure 3 Centrality levels per stakeholder group. Greater values indicate higher levels of centrality. See Appendix C for centrality levels in a table format.

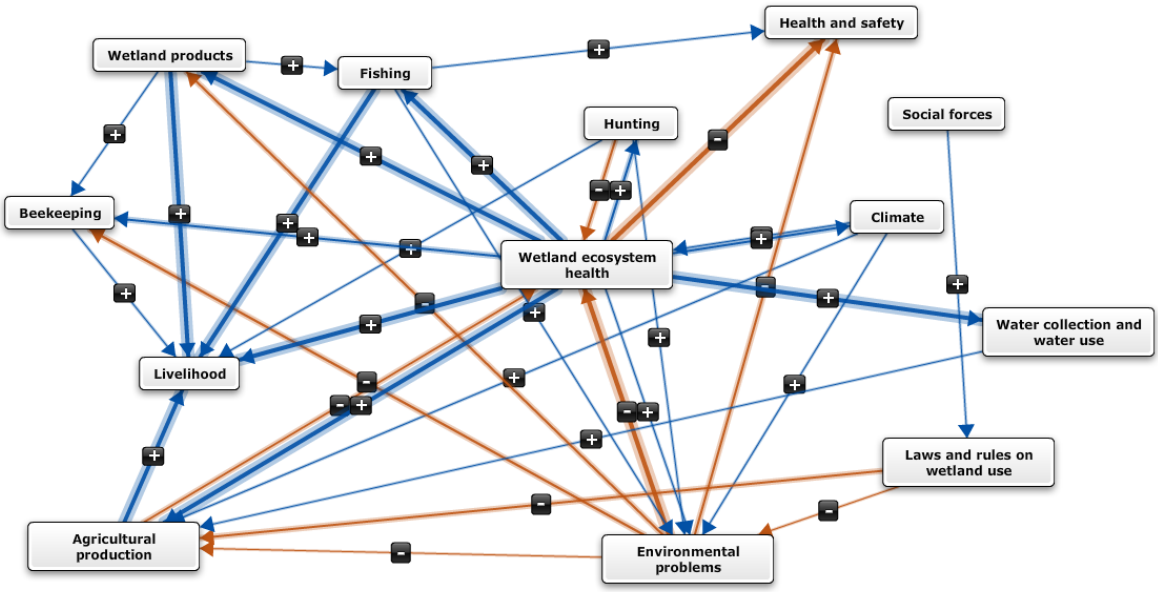

Figure 4 Aggregated community map. Blue arrows indicate a positive relationship, while orange arrows indicate a negative relationship. The strength of the relationship is depicted by the size (thickness) of the arrows: thicker arrows imply a stronger relationship.

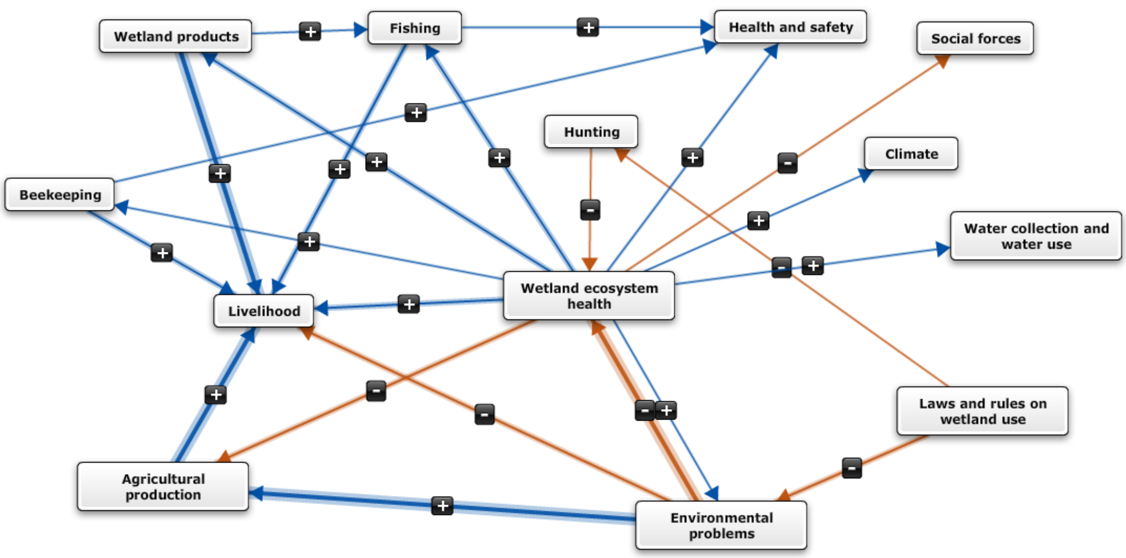

Figure 5 Aggregated group-developed map. Blue arrows indicate a positive relationship, while orange arrows indicate a negative relationship. The strength of the relationship is depicted by the size (thickness) of the arrows: thicker arrows imply a stronger relationship.

Figure 6 Simulation results by stakeholder group for a wetland conservation scenario

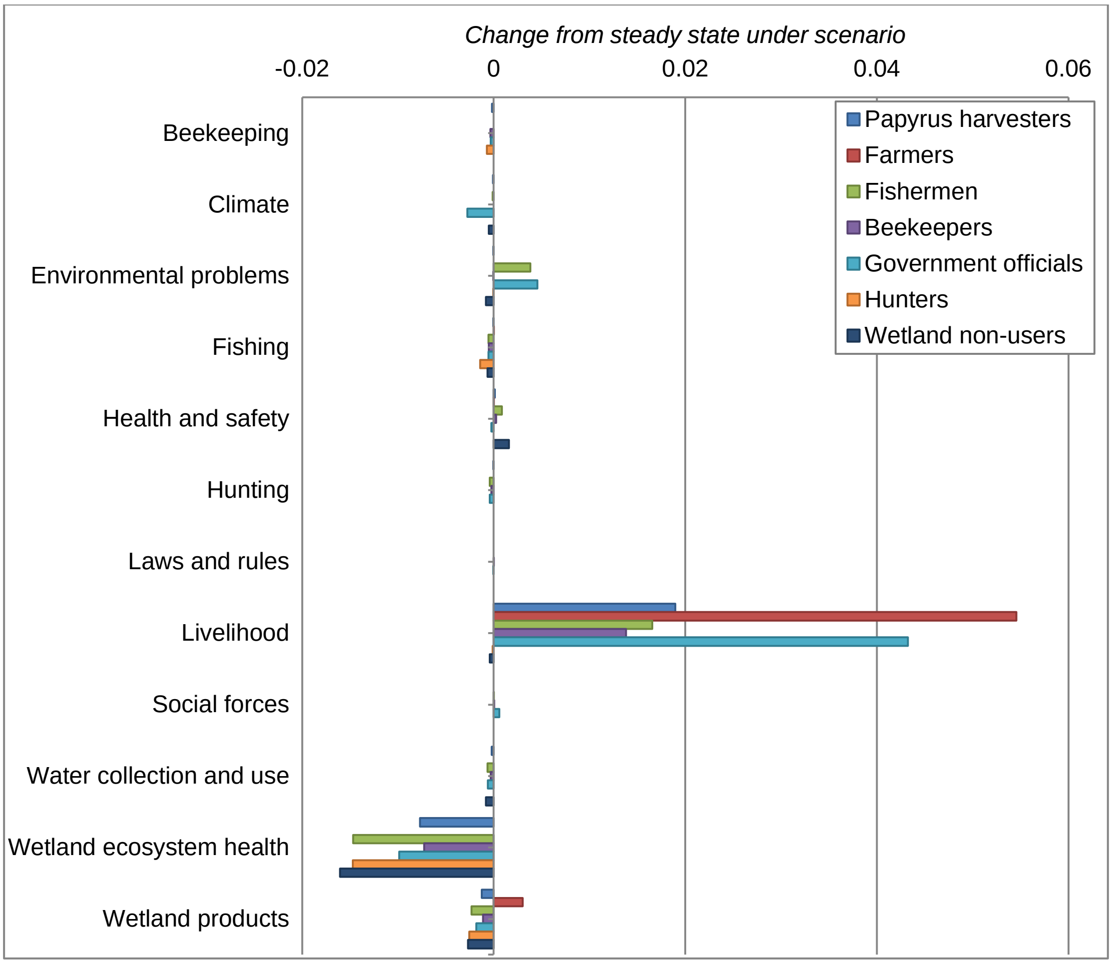

Figure 7 Simulation results by stakeholder group for wetland cultivation scenario

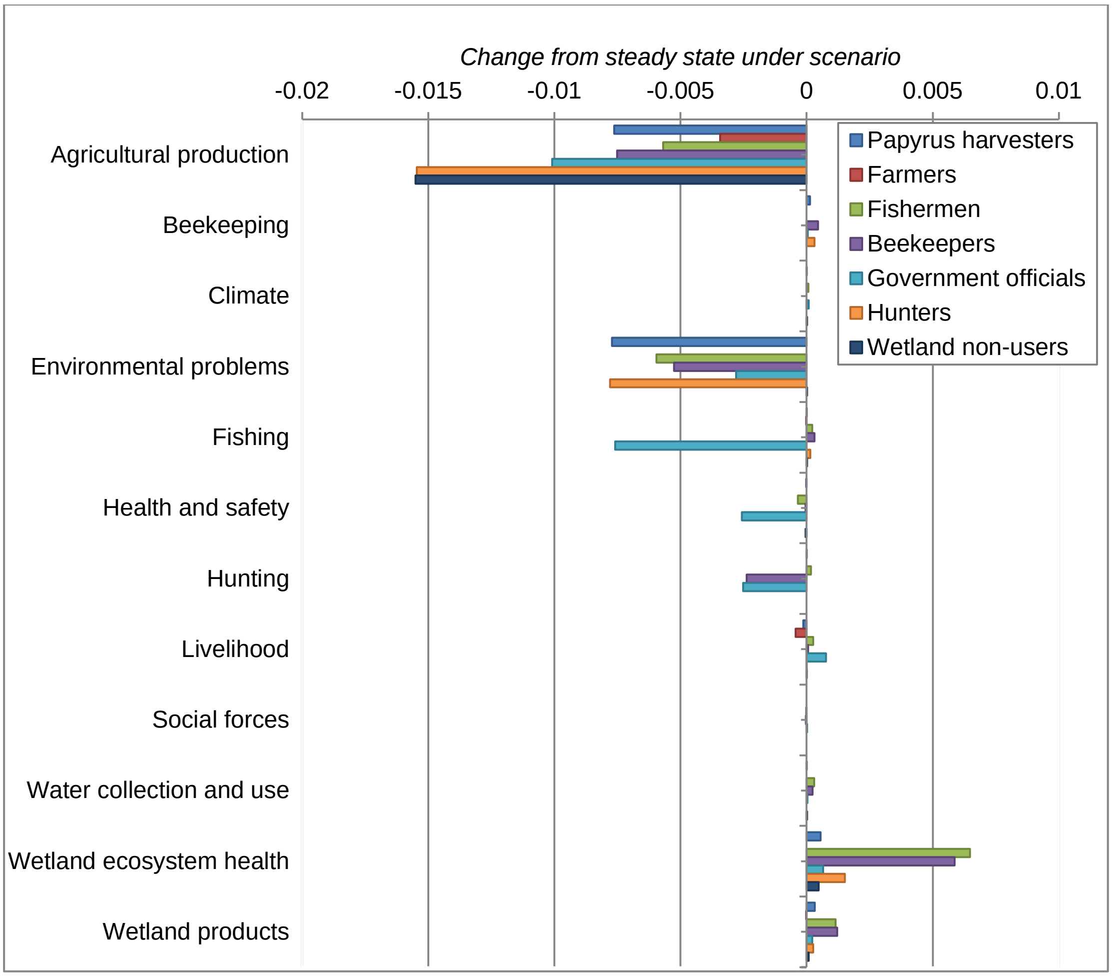

Figure 8 Simulation results by stakeholder group for the scenario on enhancement and increased local enforcement of laws and rules